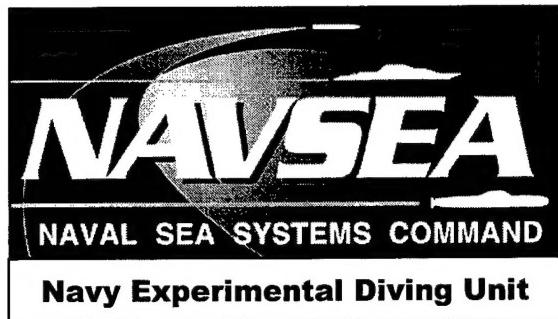


Navy Experimental Diving Unit
321 Bullfinch Rd.
Panama City, FL 32407-7015

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NEDU TR 6-01
February 2001



**EVALUATION OF AQUA LUNG
(U.S. DIVER)
“SEAMASTER” BUOYANCY
COMPENSATOR w/Fenzy Bottle**

C. J. ZANONI:

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19. ABSTRACT: NEDU was tasked to conduct a survey of commercially available buoyancy compensators (BCs) and perform testing to determine which BCs perform satisfactorily. Buoyancy compensator evaluation was conducted in three phases. Phase I included receipt inspection of the buoyancy compensator, technical review of the manufacturer-supplied documentation (instructions / repair manuals), diver orientation, and Test Pool Evaluation (surface floating attitudes if the BCs were used as life jackets). No failure mode analysis was conducted. Phase II consisted of buoyancy / lift capacity testing in the OSP at 190 fsw. Phase III consisted of manned dives in the Gulf of Mexico to test diver buoyancy control and operational characteristics.					
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INTRODUCTION

Navy Experimental Diving Unit (NEDU) was tasked¹ to conduct surveys of commercially available buoyancy compensators (BCs) and perform testing to determine which BCs perform satisfactorily in accordance with references (2) and (3). All buoyancy compensators that meet the above requirements will be candidates for recommendation to the Authorized for Navy Use (ANU) list. The purpose of this technical report is to determine if the Aqua Lung (U.S. Diver) "Seamaster" buoyancy compensator with the alternative inflation source (HP Fenzy bottle P/N 4270.43) and the Aqua Lung (U.S. Diver) twin spacer adapter kit (P/N 0834.03) buoyancy compensator meets those requirements.

METHODS

GENERAL

Each BC was tested and evaluated in three different environments: Phase I, Bench Test; Phase II; Controlled Environment (Test Pool/ Ocean Simulation Facility [OSF]); and Phase III, Open Ocean Diving. During bench testing, two qualified U.S. Navy divers evaluated each BC for the completeness and adequacy of its maintenance manuals and technical documentation, skill levels it required of divers performing routine repair and maintenance, and operation of its integrated weight belt and all components. In a controlled environment each BC was tested and evaluated for buoyancy and lift capability. During open water dives each BC was used and evaluated by at least ten qualified U.S. Navy divers in both single and double SCUBA tank configurations to a minimum of 30 fsw (9.4 msw). The conversion for msw is in accordance with reference (4).

EXPERIMENTAL DESIGN AND ANALYSIS

All BCs were off-the-shelf items; three sizes were tested: medium, large, and X-large. The Task Leader or assigned representative was present during the set-up and post-dive procedures on all BCs.

Phase I testing:

- Each model BC was evaluated by two qualified U.S. Navy divers for ease of operation and maintenance procedures.
- Average cost from five different suppliers was acquired.

Specific comments from evaluators were compiled and documented.

Phase II testing:

- All BCs of different sizes were tested to 190 fsw (59.4 msw) using the OSF. Each BC was fully inflated three times in both single and twin configurations and the average lift capacity was recorded.

Phase III testing:

- All BCs of different sizes were evaluated during a series of open water dives to a minimum depth of 30 fsw. Divers completed a human factor questionnaire after each dive. A set of statistics describing the responses and specific comments were compiled.

EQUIPMENT AND INSTRUMENTATION

No special or proprietary tools were required to perform routine maintenance or repair on the BCs.

- a. Phase I: During bench testing the following equipment was used:
 - (1) Fully charged SCUBA bottle and an approved regulator
(used to supply low-pressure air to perform equipment checks)
 - (2) Manufacturer's instructions and maintenance manual
 - (3) Miscellaneous hand tools and adapter fittings
 - (4) Weights (soft or molded)
- b. Phase II: During OSF testing the following equipment was used:
 - (1) Calibrated spring scale (Model #895, Viking Scale, Shubuta, MS), 0 to 50 pounds (0 to 22.68 kg)
 - (2) Lanyards, spinnaker shackles, and weight as appropriate to anchor the BCs to the deck in the wet chamber
 - (3) Fully charged SCUBA bottle and an approved regulator (used to supply low-pressure air)
 - (4) Personnel as required
 - (5) Weights
 - (6) HP Fenzl bottles (P/N 4270.43)
 - (7) Aqua Lung (U.S. Diver) twin spacer adapters kit (P/N: 0834.03) utilized to change BC from single configuration to twin tank configuration
- c. Phase III: During at-sea testing the following equipment was used:
 - (1) Fully charged SCUBA bottle, approved regulator, and all other personal diving equipment needed to perform a SCUBA dive
 - (2) Personnel as required
 - (3) At-sea diving platform

PROCEDURES

BC evaluation was conducted in three phases: (1) receipt inspection and technical review of manufacturer-supplied documentation, (2) OSF wet chamber evaluation (buoyancy/lift capacity at 190 fsw), and (3) Open water dives to test buoyancy control and operational characteristics.

- a. Phase I testing began with a review of the following:

- (1) Completeness and adequacy of the maintenance manuals and technical documentation
- (2) Requirements for special or proprietary tools
- (3) Skill levels required to perform routine repair and maintenance
- (4) Operation of the integrated weight system
- (5) Operation and activation of all BC components
- (6) Ease of assembly from single tank configuration to twin tank configuration
- (7) Unit price

Each diver completed a technical documentation and worksheet for operating functions and returned it to the Task Leader.

b. Phase II Testing: Buoyancy/lift capacity of the units was tested in the OSF wet chamber at depths of 190 fsw. All divers in the study were required to familiarize themselves with the contents of the user's manual, including the location of controls on the BC and procedures for donning it.

A calibrated Viking Spring Scale Model #895 was attached to the deck grating of the OSF to measure buoyancy. Each BC was attached to the scale and tested, pressurized to 190 fsw in the OSF. The buoyancy was measured and documented; at a minimum, each BC was required to provide 10 lbs of positive lift, as outlined in reference (3). The BC was also tested for leaks at depth.

c. Phase III Testing: Manned open water dives were conducted to a minimum depth of 30 fsw to determine each BC's swim characteristics. Results were documented using a diver's questionnaire.

RESULTS

PHASE I

The documentation that the manufacturer supplied on the use and technical specifications of the BC, the exploded views/diagrams of it, and the service and parts for it was unsatisfactory. No parts list or technical specifications were included within the supplied buoyancy compensator manual, but these documents were available from the manufacturer upon request. There were no requirements for special or proprietary tools needed. Skill levels required to perform routine maintenance should be those of at least a Second-Class Diver. The weights of the integrated weight system were secure, and it was easy to operate the release mechanism and reinstall them for redeployment. All BC components were easy to operate and activate. There were no problems assembling the single tank configuration to the twin tank configuration utilizing twin spacer kit (P/N 0834.03).

The manufacturer's suggested price per unit (Medium - X-Large) is \$285.

PHASE II

All sizes of the "Seamaster" BC in the single tank configuration averaged 33 lbf (Medium), 39.5 lbf (Large), and 39.5 lbf (X-Large) of positive lift at 190 fsw (see Table 1). The measured buoyancy of the "Seamaster" BC was approximately 5.7% less than the 35 lbf (Medium), 23% less than 50 lbf (Large), and 23% less than the 50 lbf (X-Large) measures that the manufacturer claimed. However, these differences might be attributed to differing test conditions, procedures, or depths that the manufacturer used.

In the twin tank configuration, the three sizes of the "Seamaster" BC averaged 30 lbf (Medium), 37 lbf (Large), and 37 lbf (X-Large) of positive lift at 190 fsw (see Table 2). The measured buoyancy of the "Seamaster" BC was approximately 14.3% less than the 35 lbf (Medium), 26% less than 50 lbf (Large), and 26% less than the 50 lbf (X-Large) measures that the manufacturer claimed. Again, these differences might be attributed to differing test conditions, procedures, or depths that the manufacturer used.

PHASE III

During the manned evaluation of the Aqua Lung "Seamaster," 20 divers tested the buoyancy compensator in both tank configurations at depths ranging from 30 to 130 fsw. On a scale of 1 – 7 (with 4.0 being the minimum mark for an overall acceptable score), this BC scored a rating of 5.30 in the single tank configuration and 5.40 in the twin tank configuration.

CONCLUSIONS

During the manned diving in open water, 50% of the divers reported difficulties in reaching the operating valve for the alternative inflation system. However, divers also commented that more time in the BC with the alternative inflation system would make it easier to operate. Using the BC in the single or twin tank configuration did not change its performance.

The buoyancy compensator "Seamaster" has an integrated weight belt system that the diver can remove and ditch from the buoyancy compensator in case of emergency.⁴ Either or both sides of the system can be ditched, to regain proper buoyancy control. We suggest that only one side be discarded at a time; this will allow the diver to see if proper buoyancy has been regained. If it has not, the other side may be ditched. Each of the weight module pockets are designed to hold a maximum of 16 lbs of molded or soft weights for a total of 32 lbs onboard weight capacity. This system is easy to use and easy to reinstall onto the buoyancy compensator.

RECOMMENDATIONS

Based on the testing and evaluation done in accordance with reference (3) and reported in Tables (1) and (2), we recommend that the Aqua Lung (U.S. Divers) "Seamaster" BC (P/N: Medium 7692.70, Large 7692.80, and X-Large 7692.90) using the Fenzy kit (P/N 4270.43) with or without the twin spacer adapter kit (P/N 0834.03) be recommended for use. In accordance with reference (6), no surface floating attitude testing was conducted. Therefore, we do not recommend that this buoyancy compensator be used as a life preserver.

Table 1. Aqua Lung "Seamaster" Alternative Inflation Source (Fenzy Bottle) Buoyancy Compensator Pull Test Data in Single and Twin Tank Configuration

Aqua Lung "Seamaster" w/ Fenzy Bottle - Single Tank Configuration					
NO.	NOMENCLATURE	BC #	PULL TEST WEIGHT (LBF)	DEPTH	INFLATION METHOD
1	Aqua Lung "Seamaster" w/ Fenzy Bottle	M	33 LBF	190 FSW	HP Fenzy bottle attachment
2	Aqua Lung "Seamaster" w/ Fenzy Bottle	L	39.5 LBF	190 FSW	HP Fenzy bottle attachment
3	Aqua Lung "Seamaster" w/ Fenzy Bottle	XL	39.5 LBF	190 FSW	HP Fenzy bottle attachment
Aqua Lung "Seamaster" w/ Fenzy Bottle - Double Tank Configuration					
NO.	NOMENCLATURE	BC #	PULL TEST WEIGHT (LBF)	DEPTH	INFLATION METHOD
1	Aqua Lung "Seamaster" w/ Fenzy Bottle	M	30 LBF	190 FSW	HP Fenzy bottle attachment
2	Aqua Lung "Seamaster" w/ Fenzy Bottle	LG	37 LBF	190 FSW	HP Fenzy bottle attachment
3	Aqua Lung "Seamaster" w/ Fenzy Bottle	XL	37 LBF	190 FSW	HP Fenzy bottle attachment

Table 1. Each size BC was tested to 190 fsw (59.4 msw) using the Ocean Simulation Facility. Each BC was fully inflated three times in both single and twin configurations, and the average lift capacity was recorded.

Table 2. Human Factors Evaluation of the Aqua Lung "Seamaster" Alternative Inflation Source (Fenzy Bottle) Buoyancy Compensator in Single and Twin Tank Configuration.

Aqua Lung "Seamaster" w/ Fenzy Bottle - Single Tank Configuration									
#9 #10 #11 #12 #13 #14 #15 #16 #17									
QUESTIONNAIRE #	Comfort	Mobility	Donning & Doffing	Neutral Buoyancy Swimming	Neutral Buoyancy Standing	Neutral Buoyancy Prone	Neutral Buoyancy Supine	Integrated Weights	Tank Attachment
1	6	6	4	6	6	6	6	5	4
2	5	5	5	5	5	5	5	5	4
3	6	5	7	6	6	5	5	4	4
4	5	5	5	6	6	6	6	4	4
5	8	7	7	7	7	7	7	5	6
6	6	6	6	6	6	6	6	5	5
7	7	7	7	5	6	4	5	5	6
8	5	6	4	6	6	6	6	7	4
9	5	5	5	5	5	5	5	5	5
10	5	5	5	5	5	5	5	5	5
QUESTION AVERAGE	5.60	5.70	5.50	5.70	5.80	5.50	5.60	4.90	4.70

Aqua Lung "Seamaster" w/ Fenzy Bottle - Double Tank Configuration									
#9 #10 #11 #12 #13 #14 #15 #16 #17									
QUESTIONNAIRE #	Comfort	Mobility	Donning & Doffing	Neutral Buoyancy Swimming	Neutral Buoyancy Standing	Neutral Buoyancy Prone	Neutral Buoyancy Supine	Integrated Weights	Tank Attachment
1	6	6	6	6	6	6	6	5	6
2	5	5	4	4	4	4	4	4	4
3	6	5	6	6	6	5	5	5	4
4	7	6	7	7	7	7	7	5	5
5	5	6	4	6	6	6	6	7	4
6	5	5	7	6	5	4	5	7	5
7	5	4	6	4	3	3	6	6	6
8	6	6	6	5	5	5	5	3	7
9	6	6	7	6	6	6	6	4	6
10	6	6	6	6	6	6	6	4	6
QUESTION AVERAGE	5.70	5.50	5.90	5.60	5.70	5.20	5.60	5.00	5.30

Table 2. A series of evaluation dives consisted of ten-man dives per BC, per tank configuration. All open water dives were conducted at a minimum depth of 30 fsw (9.4 msw). Divers completed a human factors questionnaire after each dive. A set of statistics describing the responses and specific comments were compiled. The BCs were scored on a scale of 1 – 7, with 4.0 being the minimum mark for an overall acceptable score (1 = poor, 4 = adequate, 7 = excellent).

Table 2 (cont.) Human Factors Evaluation of the Aqua Lung "Seamaster" Alternative Inflation Source (Fenzy Bottle) Buoyancy Compensator in Single and Twin Tank Configuration.

Aqua Lung "Seamaster" w/ Fenzy Bottle - Single Tank Configuration										Aqua Lung "Seamaster" w/ Fenzy Bottle - Double Tank Configuration										
		#18		#19		#20		#21		#22		#23		#24		#25		#26		
QUESTIONNAIRE #		Over All Rating		Operating Controls		AVERAGE		Wearing Gloves		Water Drag		Were You Comfortable With BC		To Many Buckles and Straps		Can 2nd DV Operate		BC of Choice		
1		6		6		6.00		Y		N		Y		Y		Y		Y		Y
2		5		5		5.00		Y		N		Y		N		N		Y		Y
3		6		6		6.00		Y		Y		Y		N		Y		Y		Y
4		5		6		5.50		Y		Y		Y		Y		Y		Y		Y
5		6		7		6.00		Y		N		Y		N		Y		Y		Y
6		5		6		5.50		Y		N		Y		N		Y		Y		Y
7		5		6		5.50		Y		N		Y		N		Y		Y		Y
8		6		5		5.50		Y		N		Y		N		Y		Y		Y
9		4		3		3.50		Y		N		Y		N		Y		N		N
10		5		4		4.50		Y		Y		Y		N		Y		Y		Y
QUESTION AVERAGE		5.30		5.40		5.30		10 out of 10		3 out of 10		10 out of 10		2 out of 10		9 out of 10		9 out of 10		YES
Overall Average		5.30																		
		#18		#19		#20		#21		#22		#23		#24		#25		#26		
QUESTIONNAIRE #		Over All Rating		Operating Controls		AVERAGE		Wearing Gloves		Water Drag		Were You Comfortable With BC		To Many Buckles and Straps		Can 2nd DV Operate		BC of Choice		
1		6		6		6.00		Y		N		Y		Y		Y		Y		Y
2		6		6		6.00		Y		N		Y		N		Y		Y		Y
3		6		6		6.00		Y		Y		Y		N		Y		Y		Y
4		6		6		6.00		Y		N		Y		N		Y		Y		Y
5		6		6		6.00		Y		N		Y		N		Y		Y		Y
6		4		5		4.50		Y		Y		Y		N		Y		Y		Y
7		6		6		6.00		Y		Y		Y		N		Y		Y		Y
8		4		4		4.00		Y		N		Y		N		Y		Y		Y
9		6		6		6.00		Y		N		Y		N		Y		Y		Y
10		3		4		3.50		Y		N		Y		N		Y		Y		Y
QUESTION AVERAGE		5.30		5.50		5.40		10 out of 10		3 out of 10		10 out of 10		2 out of 10		9 out of 10		10 out of 10		YES
Overall Average		5.40																		

Table 2. The series of evaluation dives consisted of ten manned dives per BC, per tank configuration. All open water dives were conducted at a minimum depth of 30 fsw (9.4 msw). Divers completed a human factors questionnaire after each dive. A set of descriptive statistics of the responses and specific comments were compiled. The BCs were scored on a scale of 1 – 7, with 4.0 being the minimum mark for an overall acceptable score (1 = poor, 4 = adequate, 7 = excellent).

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1. Naval Sea Systems Command, Task Assignment 98-10, *Commercial Diving Equipment Test and Evaluation*, Dec 97.
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